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VEHICLE DYNAMICS AND CONTROL

A Motion Decoupling Control Based on Differential Geometry for Distributed Drive Articulated Heavy Vehicle

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Abstract

A vehicle system motion decoupling control method was proposed to address challenges in controlling articulated heavy vehicles (AHVs). The method, based on differential geometry theory, focused on distributed electric drive AHVs. Its objective was to separate the highly nonlinear and strongly coupled dynamics system into two relatively independent subsystems: longitudinal and lateral motions. Additionally, a robust controller was designed to improve the vehicle's resistance to external disturbances like side winds. Simulation tests using a TruckSim model of a distributed electric drive AHV show significant improvements compared to vehicles without decoupling control. The rearward amplification (RA) is reduced by 4.5%, the longitudinal velocity deviation by 67.5%, and the yaw rate deviation by 69.7%. The vehicle also demonstrates enhanced stability when subjected to strong breeze disturbances. To validate the control performance in real-time systems, the hardware-in-the-loop tests were conducted, which confirms the effectiveness of the proposed control approach in practical applications.

Keywords Distributed drive · Differential geometry · Decoupling control · Robust control

List of symbols

a_1	Distance from tractor's front axle to its center of gravity, m
a_2	Distance from trailer's center of gravity to hinge point, m
b_1	Distance from tractor's rear axle to its center of gravity, m
b_2	Distance from trailer's axle to its center of gravity, m
c	Distance from tractor's center of gravity to hinge point, m
F_{Hx}	Longitudinal force applied at hinge point, N
F_{Hy}	Lateral force applied at hinge point, N
F_{yf}	Lateral force exerted by tractor's front axle tires, N
F_{yr}	Lateral force exerted by tractor's rear axle tires, N
F_{ys}	Lateral force exerted by trailer's axle tires, N
I_{z1}	Yaw inertia of tractor, kg m^2
I_{z2}	Yaw inertia of trailer, kg m^2
i	Steering ratio
K	Stability factor of vehicle
k_1	Cornering stiffness of tractor's front axle, N/rad
k_2	Cornering stiffness of tractor's rear axle, N/rad
m_1	Mass of tractor, kg
m_2	Mass of trailer, kg
M_{z1}	Active yaw moment of tractor, N m
M_{z2}	Active yaw moment of trailer, N m
m_1	Mass of tractor, kg
m_2	Mass of trailer, kg
R_1	Radius of tractor tires, m
R_2	Radius of trailer tires, m
T_{l1}	Driving moment of tractor's left wheels, N m
T_{r1}	Driving moment of tractor's right wheels, N m
T_{l2}	Driving moment of trailer's left wheels, N m
T_{r2}	Driving moment of trailer's right wheels, N m
T^*_{l1}	Desired driving moment of tractor's left wheels, N m
T^*_{r1}	Desired driving moment of tractor's right wheels, N m
T^*_{l2}	Desired driving moment of trailer's left wheels, N m
T^*_{r2}	Desired driving moment of trailer's right wheels, N m
v_{x1}	Longitudinal velocity of the tractor, m/s
v_{x2}	Longitudinal velocity of the trailer, m/s
y_1	Lateral displacement of tractor's center of mass, m
y_2	Lateral displacement of trailer's center of mass, m

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